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STUDY OF CERTAIN SEEMINGLY ABNORMAL DEFORMATIONS AND TRANSFORMATIONS OF METALS

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INTRODUCTION

When one of us suddenly came up against a case of the deformation of a metal test piece without the apparent intervention of an external force[1], we felt it our duty as metallurgical investigators to try to systematically study this type of phenomenon.

Footnote: [1]See Sciences and the Future, No. 345 (November 1975), 1

FROM MÉMOIRES SCIENTIFIQUES REVUE MÉTALLURGIE - FÉVRIER 1978

108. End footnote

Therefore, we went to J. P. Girard, who was reputed to have produced "abnormal" effects on metals and wished to conduct experiments in the presence of scientists. The purpose of this report is to describe some of the tests which we conducted with him over a period of almost two years.

Several weeks after our tests were begun, J. P. Girard informed us that he practiced prestidigitation. Some time later, two or three sources simultaneously also informed us that he had been written up in the "Magician's Yearbook." At first he worked in a somewhat obscure and roundabout fashion, resembling the style of an illusionist. In spite of this, after this initial period, J. P. Girard produced interesting effects. Various scientific personalities attended some of these demonstrations. We gradually got J. P. Girard to simplify his behavior and follow stricter procedures. But on our recordings we observed some movements which indicated muscular action.

This mixture of striking effects and questionable elements led us to make a rather lengthy critical study. We think it would be interesting to outline the main steps here.

In order to avail ourselves of varied opinions, since August 1976 we have written down all of our observations, reflections, and doubts in a provisional report which was subsequently distributed to many scientists: In this report, we mentioned what we knew about J. P. Girard as a prestidigitator and some of our doubts concerning the "props" which he could have used more or less consciously during the tests. This report was supplemented with the presentation of documents (test pieces, microphotographs, diagrams, "video" recordings), with sampling of the reliable tests and others which were not as reliable, since it would have been wrong to present too optimistic a selection. We also showed various films of external origin, thus of unequal significance, in these presentations in order to enlarge on the information on certain parts. French and foreign illusionists attended some of the presentations; they helped us to refine our opinion in certain areas. One of them discovered an indication of trickery in a film which J. P. Girard got for us without telling us that it was faked. The opinions gathered during all of these discussions helped us make the critical study of our documents and various verifications which we have made since that time. J. P. Girard agreed to some counter-tests, at least one of which is very interesting[1].

Footnote: [1]Test No. 4 of Table II. End footnote

All of this took some time, which explains the long delay between our initial tests and the appearance of this article. But we feel that this critical study has gone far enough, if not too far, and that the time has come to publish our most characteristic experiments.

Thus, the selection which we are presenting is the result of a lengthy screening process. In only twenty out of the 150 test pieces which J. P. Girard deformed or transformed in front of us or our collaborators could we positively confirm the "abnormal" nature of the effects observed. In this report we will describe eight of these cases, the most characteristic. But it must be pointed out that the majority of the tests which were eliminated were definitely valid, for we used too strict a screening process to eliminate the demonstrations which did not follow a predefined operating procedure. Other tests with extensometric gauges will be published later.

Thus, our concern for strictness eliminates rather remarkable observations concerning deformations at a distance, deformations of

objects or test pieces in the hands of the observers themselves who were above any suspicion, or those held on either side by J. P. Girard and an observer.

The tests which will be described were conducted under our own responsibility with the authorization of Pechiney-Ugine-Kuhlmann. We would like to thank those of our collaborators who were willing to help us in the delicate study of this controversial area, in particular Mr. J. Rauch, Mr. G. Jollant, and Mr. B. Dubost. We would also like to acknowledge Professor J. B. Hasted, professor of physics at Birbeck College of the University of London, for agreeing to sponsor a test in his laboratory.

Description of Tests

In order to make it impossible for J. P. Girard to surreptitiously bend a test piece, we often used bars with a rather large cross section made of various metals: in particular, aluminum and light alloys (test pieces 250-350 mm long and 8-17 mm in diameter), but also copper, soft steel, stainless steel, and magnesium. We determined the forces (bending moments) necessary to bend our test

pieces by measurements and calculations. In order to be able to compare the values of the resistance of the test pieces to the forces which they could have withstood if faking by surreptitious bending occurred, we determined the maximum moment which a man can create when seizing a test piece in two hands using all of his strength... which could not go unnoticed! For this purpose, we used a dynamometric key with handles 400 mm long, which we tested with many individuals. The maximum moments vary with the individuals from 20-38 N•m; J. P. Girard created 26 N•m with a very visible effort. These values were confirmed by direct tests on bars; an example of this will follow (session of 27 October 1976).

Since our purpose here was neither to describe all of these tests, nor to make a critical review, we selected the two most typical sessions for this article:

Session of 31 March 1976 at the Aluminum Technical Center.

Experimenters: J. Rauch and G. Jollant, with the aid of a video recording assistant.

During this session, in a room adjacent to the room J. P. Girard was in, G. Jollant, an experimenter, took a bar of hardened duraluminum of alloy AU4G, state T4 (i.e., hardened, aged) 250 mm long and 8 mm in diameter. Its high critical bending moment (15 N•m) makes it impossible to bend without a visible effort. G. Jollant rolled it on a desk, stated that it was not out of round, marked it, and placed it himself in a glass tube which he closed with a stopper. This is the only time which we were able to arrange it so that J. P. Girard did not touch the test bar to be bent before it was enclosed in a tube.

G. Jollant brought the closed tube to J. Rauch, who immediately gave it to J. P. Girard, and everything was filmed from then on. Either the stopper, the bar in the tube, or both were always visible. After concentrating and declaring that he felt something, J. P. Girard gave the tube, still closed, to J. Rauch. Mr. Rauch uncorked it, removed the bar, which was visibly bent, and placed it on the desk, then on a flat bar in order to bring out the bend, which was thus made very obvious. This bend was 2 mm.

Session of 27 October 1976 at Grenoble

Experimenters: J. Bouvaist and B. Dubost.

Here we will describe the test made on the thickest bar. This was a bar 17 mm in diameter and 300 mm long made of alloy AU2 (2.05c/o copper) in state T4 (hardened in cold water and aged for one year). Reference marks were engraved in the mass of this bar, and the placement of small characteristic flaws were noted. It was taken to the experimental site in a different car from the in one which J. P. Girard was transported, and it was the only one of its kind in the experimental batch.

This bar was preliminarily subjected to bending tests by very strong men, and only one man weighing 140 kg was able to make a slight, but significant, deformation after smearing his hands with magnesium (a bend of 0.6 mm corresponding to an applied moment of 38 N•m). Then the bending plane was marked by scratches made on the two ends. Previous tests made it possible to confirm that even using a fixed half-length support, an average man could not even increase

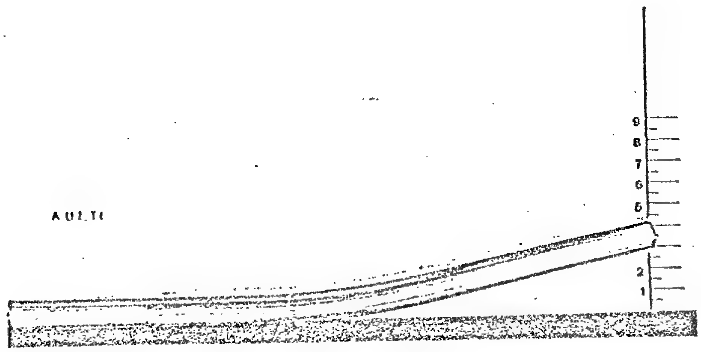
this deformation by applying his entire weight (65 kg) to both ends.

During the tests, the two experimenters sat at about a meter away on either side of J. P. Girard, who worked in shirtsleeves, with his sleeves rolled up, without contact. J. P. Girard deformed this bar four times in succession by holding one end in his right hand and lightly touching the free part with his left hand (bends 1 and 2) or by placing his left hand five cm above the specimen (bends 3 and 4). After each deformation, one observer took the profile of the test bar, while the other remained next to J. P. Girard. The two largest deformations (3 and 4) could be seen with the eye; both were produced toward the bottom during a time on the order of 10-20 seconds. After each deformation, it was verified that no heating up could be detected by touching the bar with the hand, and that the bends made without force by J. P. Girard were all in the same plane (inclined by 34° relative to the initial bending plane mentioned above), marked by the grooves indicated above. These grooves also made it possible to verify that the same bar was being used at all times. Immediately following the experiment, the specimens were placed in a briefcase and taken to the laboratory.

We will now describe the laboratory tests:

First, in the laboratory we verified that all of the marks, grooves and flaws which were originally made on the bar were present on the bar returned from the experiment. This made it possible unequivocally confirm that there was no substitution of the specimen. Figure 1 shows a picture of the bar after the experiment.

Fig. 1. Photograph of AU2 bar 17 mm in diameter after bending. Scale in centimeters.



The following tests were made for the nondestructive characterization of the charges made in the bar - more specifically, in section A - corresponding to the maximum curvature. We can see:

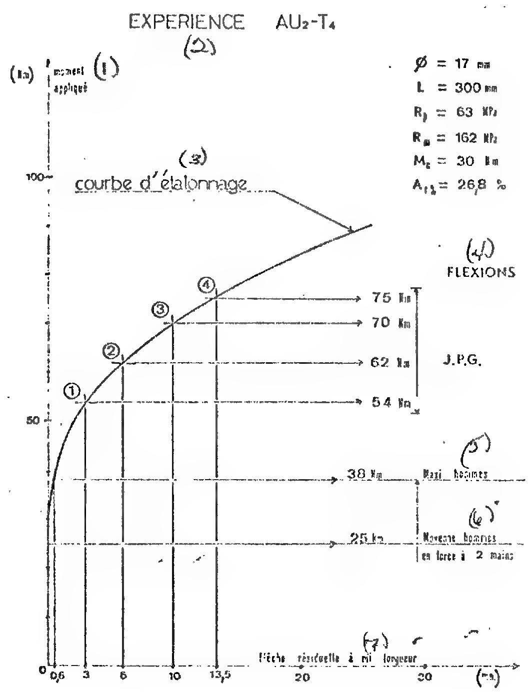
- a significant increase in the hardness of the two grains located in the bending plane, reaching a maximum of 11 points Vickers (or 27o/o) in section A, which corresponds to the maximum curvature. The length of the zone in which the hardness exceeds the initial value is around 120 mm (60 mm on either side of section A).

- the hardness measured on the circumference of section A perpendicular to the bending plane is the maximum in the bending plane, and varies linearily with the side relative to the neutral line, as in the case of simple bending.

In order to determine the moment which must be applied to the bar by mechanical bending in order to obtain the permanent bend observed, we mechanically bent a control bar which was identical to the preceding one with a distance of 200 mm between the fixed supports. The variation in the residual bending measured as a function of the moment applied is given in Fig. 2. From this we can conclude that in order to obtain the bend observed on the bar bent by J. P. Girard (fr = 13.5 mm), it would be necessary to apply a moment

M of around 75 N•m, or two and a half times the critical moment Mc = 30 N•m, and twice the moment exerted by the strongest man whom we tested. The total deformation energy can be calculated at 11 J.

Fig. 2. Diagram of bending as a function of the moment applied to a control bar identical to that in Fig. 1. KEY: (1) Moment applied. (2) Experiment. (3) Calibration curve. (4) Bends. (5) Max. for men. (6) Mean for men with the force of two hands. (7) Residual bending at half-length.



The preceding results make it possible to completely exclude the hypotheses of surreptitious deformations of muscular origin which might have escaped notice by the observers. Furthermore, the fact that "normal" consolidation of the deformed zone is observed makes it possible to exclude the surreptitious use of thermal or chemical means to decrease the local mechanical strength of the alloy.

In conclusion, the set of observations made during and after the experiment on the duraluminum bar deformed by J. P. Girard during the experiment of 27 October 1976 makes it possible to conclude:

- that the successive deformations realized were not and could not have been produced by the normal muscular force of the subject,

- that the final deformation obtained was in all ways comparable to that which would be obtained by applying a point force of 1500 N in the middle of the bar when resting on two supports.

Tests on Stainless Steel in Closed Tubes

Materials and Working Conditions

During the session at the Aluminum Technical Center on 25 March 1976, three experimenters (C. Crussard, J. Bauch and G. Jollant) and four other spectators observed martensitic transformations, with or without deformation, of test pieces made from a cast of austenitic stainless steel with a special noncommercial composition which had previously been used for studying the martensitic transformation by deformation. This cast essentially contained: Cr = 17.8%, Ni = 7.4%, Mn = 1.56%, Si = 0.36%, C = 0.050%, N = 0.034%.

Two test pieces left over from this study were used for this purpose. These were cylindrical test pieces (7 mm in diameter and 85 mm long) with smooth heads 12 mm in diameter. They were subjected to hardening in air at 1050°C (one hour in a salt bath), finishing treatment, and nitrofluoric corrosion, which gave the body of the test piece a matte look. The resultant structure is nonmagnetic, except for several parts of the machined surface layer. The martensitic transformation points in this state are: Ms = 140°C and

Md = +90°C.

These two test pieces were given to J. P. Girard for several days. At the beginning of the session, they were marked No. 2 and 3 in large numbers circled with an irregular circle. Another test piece, marked No. 1 in the same manner, was used for another test which was not significant and will be used again later for a simulation counter-test. Its mark can be seen in Fig. 5. This was the first time that test pieces of this type were used with J. P. Girard and that they were marked like this. These were the same test pieces, marked in this manner, which were taken at the end of the test under the conditions which we will see; there was no possibility of substitution.

After marking, one of us (C. Crussard) verified the straightness of these test pieces (Nos. 2 and 3) by rolling them; they were not "out of round." He also verified their magnetic state. A quick and simple method of evaluating point-to-point magnetism for this purpose consists of using a small powerful horseshoe magnet made of Ticonal 1500 (polar surfaces of 7x4 mm^2, 8.5 mm apart) suspended at the end of a chain. To make the measurement, one changes from a position in which the magnet is in contact with the test piece, with vertical suspension; the test piece is gradually withdrawn until the magnet is

pulled away. Measuring the horizontal distance from the magnet to the test piece at this point D, and knowing the mass of the magnet (22 g) and the length of suspension, we can calculate the pulling force F. During this verification in the middle of the two test rods and on the heads, the distance D defined above did not exceed 2-3 mm. This corresponds to a pulling force F on the order of 0.01 N, due to some traces of surface martensite caused by machining.

After this check, the test rods were placed on the desk behind which J. P. Girard was working (in rolled-up shirtsleeves) in the field of view of the video camera, which did not turn away from them (while J. P. Girard worked with other test pieces and made an attempt at a light-alloy bar without leaving his seat) until the following experiments were begun:

a) J. P. Girard carefully grasps test bar No. 2 by one head and without exerting force (the film makes it possible to confirm this), places it in a tube and stops it with a cork (always in front of the camera), takes the corked tube squarely in his hand (the left hand, with the cork always remaining visible), and concentrates. He then gives the tube to C. Crussard and does not touch the test piece from this time on.

C. Crussard removes the test piece from the tube: it has a

slight bend, but very close to one end, visible to the eye, and which he verified by rolling the piece. The verification with a magnet indicates very strong local magnetism near this same end (see Table 1). Since the entire operation was filmed, no substitution could have taken place. C. Crussard returns the test bar to its box for future study;

b) J. P. Girard takes test bar No. 3, which has remained visible throughout this time. The same operations as for No. 2 are performed, except that one spectator, at one time, blocks the camera. After J. P. Girard had concentrated, C. Crussard took the corked tube back, removed the test piece from it, and rolled it. This test piece remained straight, but nevertheless its local magnetism was similar to that of test piece No. 2, but this time without deformation. It was returned to the box, also for study.

Table 1. KEY: (1) Measurement. (2) Test piece. (3) Bending of one side. (4) Bending of the other side. (5) Mean bending. (6) Pulling force f of the magnet (N). (7) one head. (8) end of cylindrical shaft. (9) middle. (10) other end of cylindrical shaft. (11) other head. (12) Maximum value.

(1) Mesure	(2) Eprouvette n° 2	(2) Eprouvette n° 3
(3) Flèche d'un côté y 1 (mm)	2,5	< 0,3
Flèche de (4) l'autre côté y 2	1,7	< 0,3
Flèche (5) moyenne $y = \frac{y1 + y2}{2}$	2,1	< 0,3
(6) Force d'arrachement f de l'aimant (N) :		
(7) une tête	0,12 (*)	0,03
(8) extrémité du fût cylindrique	0,15	≥ 0,22
(9) milieu	0,02	0,03
(10) autre extrémité du fût cylindrique	0,02	0,02
(11) autre tête	0,05	0,01

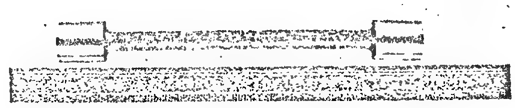
(*) Valeur maximale. (12)

Initial Measurements

The next day, C. Crussard evaluated the magnetism and deformations. The same magnet was always used to evaluate magnetism; the pulling forces F defined above are indicated in Table 1 (at close to 0.01 N). In order to evaluate the deformations Y, one of the heads was placed against a ruler and the distance between the other head (inside) and the ruler was measured. We confirmed that the test pieces "ran true" at the beginning of the test.

The bend close to one head can be seen very clearly in Fig. 3.

Fig. 3. Photograph of stainless steel test piece No. 2 after the experiment.



Laboratory Tests

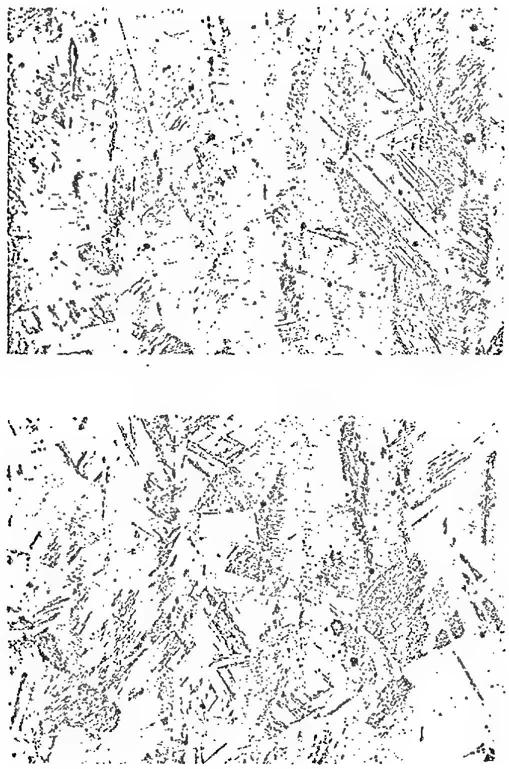
Various tests, also destructive, were made on test piece No. 2. The bar was electrolytically cut even with the magnetic head. Thus, it was possible to insert the magnetic end of the cylindrical part of the bar into the spool of a Sigmatest device: the specific saturation magnetization is 2.8, which corresponds to a proportion of 1.9% of the magnetic phase (α').

For test piece No. 3, the nondestructive X-ray study revealed martensites α' and ε in the magnetic zone, the latter in a high proportion, in addition to austenite.

Microphotographs (test piece No. 2) on a surface polished mechanically, then electrolytically (Fig. 4a and 4b) reveal a mixture of martensites ε and α'. Compared with previous studies made of this steel, we can confirm that these structures have neither the facies of a martensite obtained by cooling, nor that of a martensite produced by the densitization of austenite by heating it. This could only be martensite from deformation (with some traces of martensite due to the preparation of the ground surface). The martensite density appears to be rather uniform over the entire cross section; in spite of the uncertainty which always accompanies micrography due to the

field selection, Figures 4a and b show comparable appearances on the surface and in the interior. The amount of martensite observed on these micrographs corresponds to those which are obtained with this steel by tensile strain of 5-10%; thus, it is much more intense than that which would correspond to the slight bending observed (Fig. 3). Its localization is very surprising.

Fig. 4. Micrographs of the locally transformed zone of stainless steel test piece No. 2 (a) near the surface, (b) in the interior.



Simulation Tests

The local magnetism of the head of test piece No. 2 could not have been missed in the verification made at the beginning of the test, which was focused especially on the heads.

Nevertheless, since two confirmations are better than one, we asked ourselves if we could imagine a metallurgical process capable of producing these localized martensites while leaving the test pieces completely straight or merely slightly bent.

Since we are dealing with cold-rolled martensite, we must work with deformation. The closest means of reproducing its localization with this abundance near one head is alternating bending. We conducted tests on another test piece, No. 1, which was initially nonmagnetic: it was necessary to place one head in a vice, bend the bar by around 30°, and straighten it. But due to the special properties of this steel, the test piece was very visibly formed into an S (Fig. 5). In order to straighten it back out, it would be necessary to tool a die and restamp the piece on a press! Another difference: on test piece No. 1 thus treated, the magnetism on the end of the shaft was comparable to that of test piece No. 2, but the head was not magnetic, which is obviously normal.

Fig. 5. Test piece of stainless steel No. 1 after a simulation test.

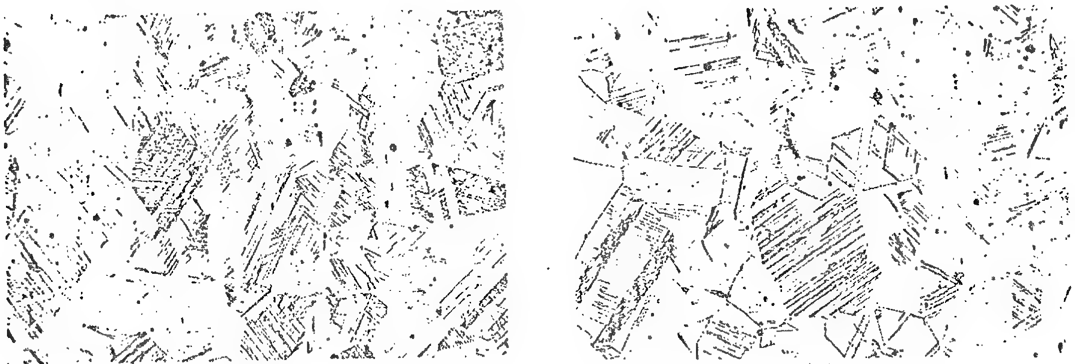
A micrographic test made on another test piece which was bent even more and straightened reveals cold-rolled martensite, but with a very distinct heterogeneous distribution: the martensite density is lower in the interior than on the surface (Fig. 6a and b), which is normal, but which differs from test piece No. 2. In order to obtain uniform density in the cross section and in the amount observed, it would be necessary to be able to create tensile strain deformation localized on the end of the shaft and in the head (on the order of 5-10% for test piece No. 2, and at least 10% for test piece No. 3), but which would not appreciably change the diameters of either the shaft or the head[1].

Footnote: [1]For test piece No. 3, a slight decrease in the cross section (0.5%) was measured in the zone which became magnetic. We will point out that we could have also considered simulation by

twisting, but we could not see how this could result in deformation localized near one head and in it. End footnote

It would be necessary to have a series of hammering out and kneading cycles, all done without leaving a mark on the test bar!

Fig. 6. Micrographs similar to those in Fig. 4, but for a test piece subjected to a simulated test: (a) near the surface, (b) in the interior.



(a) (b)

Conclusion

The group of observations described above makes it possible to state:

- that a local martensitic transformation was created in two test pieces during the test, accompanied by slight bending near one head on one of them;

- that we were unable to think up a single simple metallurgical operation which was capable of exactly duplicating the structures observed in the transformed zones.

Local Changes in Hardness of Metal Plates

J. P. Girard performed this experiment four times in different places and in front of different observers. During the first session (27 October 1976), one of the experimenters suggested that he improvise a new type of test: hardening a metal plate in attempt to "compress" the metal. Except for a few close details which will be pointed out, the experimental procedure used for this test, as well

as for the three others, was as follows: J. P. Girard was given a duraluminum plate whose dimensions, composition and reference mark were known only by the experimenter (and which were different for each new experiment). Initially, J. P. Girard came into contact with the test piece by rubbing it or touching it with his fingers under the close supervision of the experimenters. The experimenter then placed the test piece in a corked glass tube after verifying its straightness and the reference mark. Then the tube was given back to J. P. Girard for the test. The test piece remained in the tube until the laboratory test. For test No. 4, the phase in the glass tube was eliminated, since it provided no additional guarantee after the initial procedure, which permitted hand contact during the initial phase.

Test Materials and Working Conditions

The four plates which were changed were made entirely of duraluminum in state T351 (hardened at 505°C in cold water, relaxing stretching of 1.2-2%, aging for at least 48 hours). Two compositions were used (quaternary aluminum alloy A-U4SG with a noncommercial composition, and industrial alloy 2017). An anomymous symbol engraved on the metal of the plate and which was different for each experiment

permitted the observers to unequivocally identify the test plate by a simple glance. Each plate came from a batch of identical plates which were subjected the same treatment, and the control plates of each batch were preserved in the laboratory for comparison and future simulation tests. Table II summarizes the places and the characteristics of the test data of the four experiments.

Table II. KEY: (1) Test. (2) Date. (3) Place. (4) Observers. (5) Initial characteristics of specimen. (6) Type. (7) Dimensions. (8) Reference mark. (9) London. (10) and. (11) ball-testing. (12) Tooling + ball-testing.

(1) Essai	(2) Date	(3) Lieu	(4) Observateurs	(5) Caractéristiques initiales de l'échantillon		(6) Nature
				(7) Dimensions	(8) Repère	
1	27.10.76	Grenoble	J.B. (10) et B.D.	16 × 2,5 × 150	11 - I	A-U4SG-T351
2	25.11.76	Lyon	J.B., P.G. (10) et J.G.	14 × 2,4 × 160	11 - J	A-U4SG-T351
3	25.11.76	Lyon	J.B., P.G. (10) et J.G.	14 × 2,6 × 160	11 - H	A-U4SG-T351 + billage (11)
4	10.10.77	(9) Londres	J.B. (10) et J.H.	12 × 3,0 × 160	VG	A-U4G-T351 (12) usinée + brillantée

Observations During Experiment

First Test:

During the phase of contact of the tips of the fingers (~2 min), we sudcessively observed two slight bendings of plate 11-I of (+1 mm) and (-0.5 mm), respectively, in opposite directions from each other. Then the test piece was placed in the glass tube with a total residual bend of +0.5 mm (the slightly convex grain corresponded to the engraved surface). The tube was then given back to J. P. Girard twice (5 min).

Second Test:

No bending before being placed in the tube. Length of exposure: three minutes.

Third Test:

Test piece 11-H was preliminarily shot-peened over the length of the two surfaces to see if additional local hardening was possible. Duration: around three minutes, without deformation.

Fourth Test:

Test piece VG was tested twice by J. P. Girard (duration of exposure: twice for two minutes).

Laboratory Tests

For the four tests, comparative examinations of the engraved marks, dimensions, weights, and the marks of initial hardness of the test pieces confirmed that the test pieces returned to the laboratory were definitely those which were prepared for the experiments.

Hardness:

After electrolytic polishing, the hardness was measured with a Vickers microhardness meter under a load of three kg (~30 N) on the two surfaces of the test pieces subjected to the experiments, as well as on the control pieces kept at the laboratory. The marks were made with spacing of from one to two mm (depending on the case). Double-blind countermeasures used by different operators (for tests 2 and 4) led to equivalent results.

The results obtained by this technique, two cases of which are shown in Figures 7 and 8, make it possible to reveal appreciable simultaneous increases in hardness on the two opposing surfaces. The lengths of the modified zones and the maximum increases in hardness are reorganized in Table III. Considering the dispersion (characterized by the typical deviation indicated in parentheses at the second-to-last column), in a completely valid manner, these observations show that the metal was changed during the four tests.

Fig. 7. Hardnesses measured on the two sides of light-alloy test piece 11-I, after test. KEY: (1) Vickers hardness. (2) Test piece 11-I. (3) Side. (4) Load. (5) Distance to the marked end.

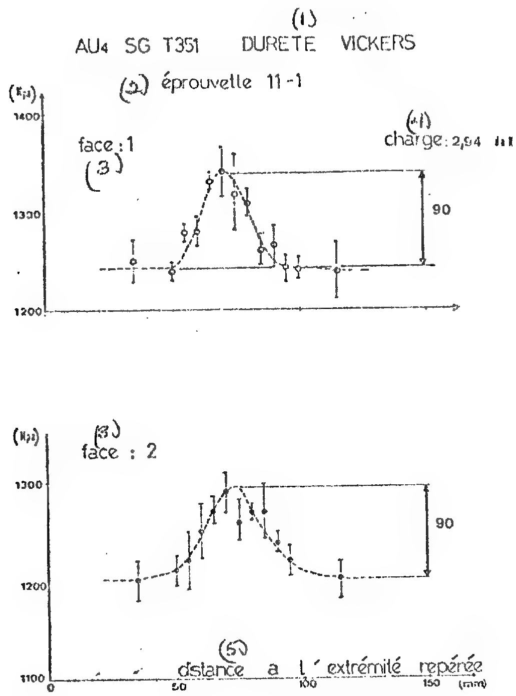


Fig. 8. Hardness measured on the two sides of light-alloy test piece VG, before and after test. KEY: (1) Vickers hardness. (2) Plate VG. (3) Load. (4) Marked side. (5) Unmarked side. (6) Distance to marked end. (7) Hardness at mid-width (°) before/(+) after experiment.

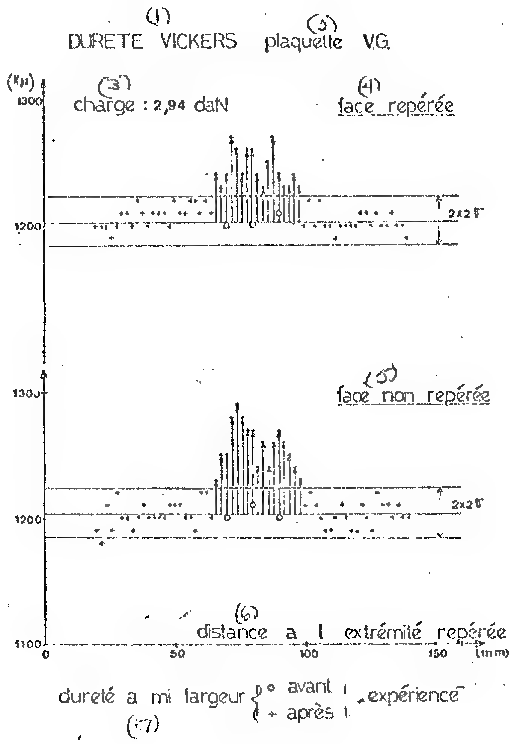


Table III. KEY: (1) Test. (2) Test piece. (3) Maximum hardness in the changed zone (MPa). (4) Initial hardness. (5) End of plate. (6) Control (standard deviation). (7) Significantly changed length (mm). (8) Side.

(1) Essai	(2) Eprouvette	(3) Dureté maximum dans la zone modifiée (MPa)	(4) Dureté initiale		(7) Longueur significativement modifiée (mm)
			(5) Extrémité plaquette	(6) Témoin (écart-type)	
1	11-I	(8) Face 1 1340	1240	1220 (15)	20
		(8) Face 2 (R) 1290	1200	1230 (14)	30
2	11-J	(8) Face 1 1340	1180	1180 (20)	20
		(8) Face 2 (R) 1310	1190	1200 (21)	20
3	11-H	(8) Face 1 1420	1290		20
		(8) Face 2 (R) 1380	1260		15
4	VG	(8) Face 1 (R) 1270	1200 (7)	1210 (15)	35
		(8) Face 2 1290	1200 (9)	1200 (10)	35

We can see that the maximum hardenings observed range from 6% (test 4) to 12% (test 2), with an average of 8%. Six Vickers impressions were made before the experiment at mid-length during test 4, since hardening always occurred in this zone in the preceding tests, yielding hardnesses of 1200-1210. This makes it possible to completely eliminate the hypothesis of the nonuniformity of the previous hardness. We will point out in passing that this test is

Approved For Release 2000/08/10 : CIA-RDP96-00787R000200010003-8

particularly interesting because it was conducted in England by Professor J. Hasted, and because the hardnesses were remeasured "blindly" and confirmed in an independent English laboratory at the Electrical Research Association.

Internal Strains:

Two techniques were used to reveal possible differences in residual longitudinal strains in the modified zones. The technique of superficial measurement by X-ray diffraction (the $\sin^2 \psi$ method) used on specimen 11-I indicates a significant change in the residual longitudinal strain on the two opposing sides of the modified zone: essentially, we see residual strain of -80 MPa on the unmarked side (slightly concave), and of +80 MPa in the opposing grain (marked). On the unchanged ends, we find again the state of internal strain which is normal for this metallurgical state (T351), or $\sigma R \simeq -15$ MPa.

This point was confirmed by measuring the relative deformations created on side two during gradual chemical treatment of the entire opposing side (1) on test piece 11-J. Using this technique (called the Rosenthal-Norton method), we observe a considerable and significant variation in the calibration mark located straight above

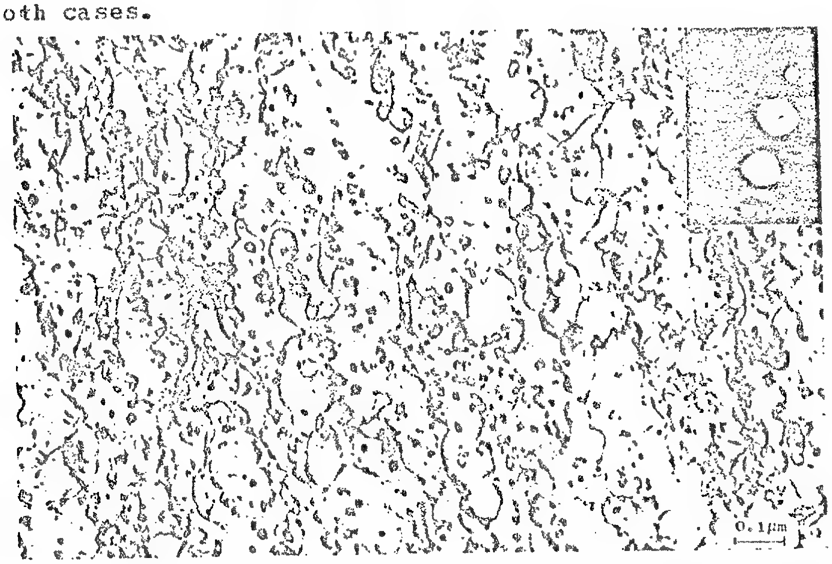
the modified zone, while a mark located on the same grain, but 25 mm from the modified zone, exhibits normal behavior similar to that of the two marks on the control piece. Thus, we can unambiguously conclude that the local change in hardness is associated with the local change in the state of residual strain in this zone.

Microstructure:

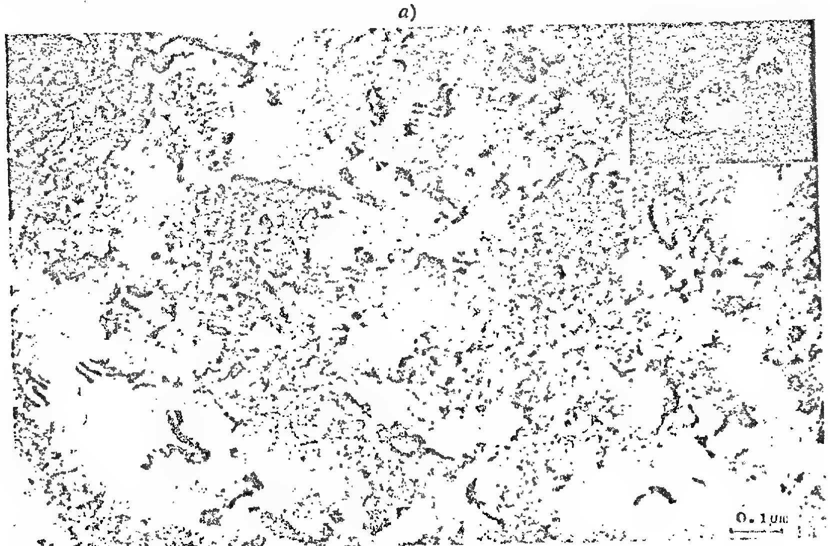
The test pieces modified during tests 1 and 2 and the corresponding controls were examined under a transmission electron microscope (100 kV). Thin slices whose thickness was carefully reduced in order to avoid any deformation were taken parallel to the surface at mid-thickness and on the two opposite sides of the modified zone of test piece 11-I, as well as in the modified surface zone (side 2) of test piece 11-J.

In both cases, we can see that the modified zones have characteristic microstructure with a very high density of small dislocation rings around 200 angstroms in diameter (Figures 9a and 10a and b). At mid-thickness we find a lower ring density, but one which is significantly greater than in the initial metal taken from the end of the test piece (Fig. 9b) and from a control.

Fig. 9. Electron micrographs of the thin slice and electron diffraction diagrams of light-alloy test piece 11-I: (a) surface hardened zone; (b) unchanged part. Conditions of identical contrast in both cases.

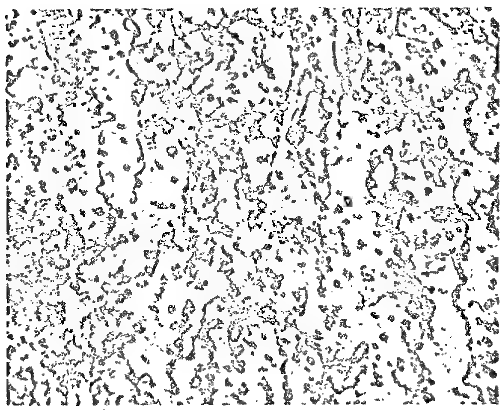


a)

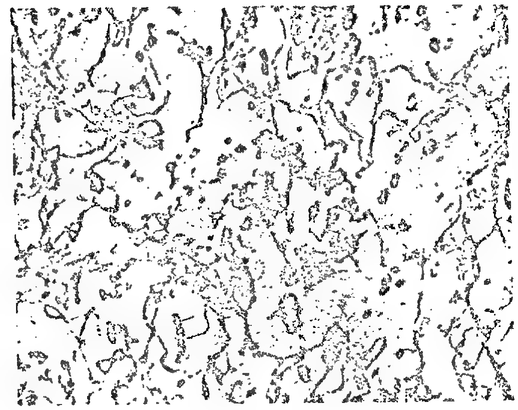


b)

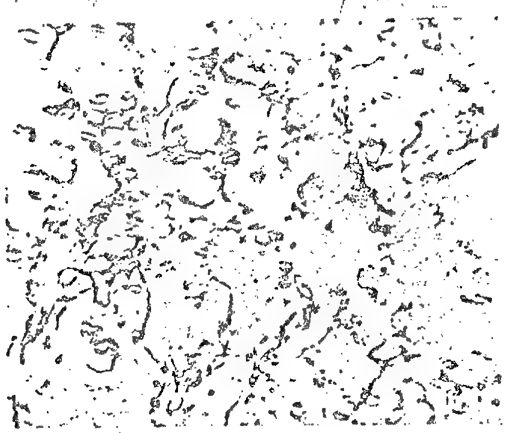
Fig. 10. Electron micrographs of modified surface zones with enlargement of 64,500 (before reduction). a) Test piece 11-I, test with J. P. Girard, side 1. b) Test piece 11-I, test with J. P. Girard, side 1. c) Test piece for shot-peening simulation. d) Test piece for simulation by compression on a stamp.



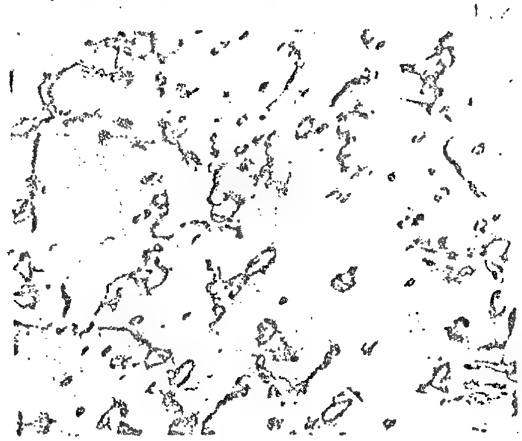
a) Eprouvette 11-I, essai avec J.P. Girard, face 1.



b) Eprouvette 11-I, essai avec J.P. Girard, face 2.



c) Eprouvette de simulation par grenaillage.



d) Eprouvette de simulation par compression à la presse.

For test piece 11-I, comparative counting of the rings visible in the section (110) was realized a: g = [111]s > 0. After measuring the respective thicknesses of the different plates, the results given in Table IV were found (mean for five fields).

Table IV. KEY: (1) Sampling. (2) Density of visible rings. (3) Relative density compared to control. (4) Control. (5) Modified zone. (6) Mid-thickness. (7) Side.

(1) Prélèvement		Densité de boucles visibles (2) (cm^{-3})	(3) Densité relative par rapport au témoin
11-I (témoin) (4)	HV = 1240	$7{,}4 \cdot 10^{13}$	1
11-I zone modifiée (5)	(7) face 1 HV = 1340	$130 \cdot 10^{13}$	18
11-I zone modifiée (5)	(7) face 2 HV = 1290	$84 \cdot 10^{13}$	11
11-I mi-épaisseur (6)		$61 \cdot 10^{13}$	8

Summing up, we will note that the changes J. P. Girard produced in the duraluminum plates which were given to him reveal, simultaneously:

- surface hardening on the order of 8% located on the two sides of the plates over a length which can reach 40 mm and a width of 10-15 mm;

- the modification of the residual surface strains in the modified zone;

- the creation of a particular microstructure in this zone with a very high density of small dislocation rings (ϕ200 angstroms);

- the absence of macroscopic bending strain (except for test 1 - see above).

Simulation Tests

As in the case of stainless steel, we sought double confirmation by trying to figure out a simple means of deformation by which the

preceding states could be simulated.

First, we will point out that the electron micrographs indicate that the Guinier-Preston zones are not dissolved and are the same at the end of the test as in the original state. This eliminates any simulation by heat treatment: in particular, by surface heating (induction or optical radiation). Thus, we had to develop mechanical simulation tests.

Alternating Bending

Since hand contact was permitted during the first phase of the experiment, we might wonder if a surreptitious alternating bending operation in the plastic range would be enough to cause the changes observed.

Alternating bending tests made on controls permitted us to see that it was necessary to introduce total plastic flow of at least 5% by alternating bending in order to obtain hardening on the order of that which was observed previously (~8%). This requires bending the test piece very intensively until a radius of curvature of 50 mm is reached (which corresponds to a bend on the order of 30, which is

incompatible with the observations made), then straightening it by bending it in the opposite direction.

However, this simulation does not permit us to duplicate the structural state observed on the test pieces modified by J. P. Girard. In fact, by electron microscopy we then observe mazes of dislocations in the hardened zones, but not the significant increase in the number of dislocation rings.

Compression Test on a Press

A local compression test of control plate 11-U conducted on a press at 300 MPa ($\sigma e \simeq 220$ MPa) made it possible to obtain hardening on the surfaces coming in contact with the stamp and the table, respectively, close to that which was sought (ΔEV = 140 MPa) with microstructure similar to the microstructure observed on the modified test pieces (Fig. 10d), but with a lower ring density. However, we observe a 13% decrease in thickness and a uniform change in the cross section of the structure and in hardness, which is not true of the test pieces "hardened" by J. P. Girard. Furthermore, measurements of the thickness of the plate revealed a reduction in thickness on the order of 2% straight above the modified zone.

Shot-Peening Test

A surface shot-peening test of the two opposing sides of the control (11-M)[1] made it possible to simulate the essential parts of the points which we were trying to reproduce: surface hardening ΔHV of 70 MPa, the absence of permanent bending, and analogous microstructure (heterogeneous in thickness with a maximum dislocation ring density in the vicinity of the surfaces).

Footnote: [1]Working conditions: Matrasur machine, air pressure - 7 bars, flow rate - 0.85 m^3/mm, glass balls (ϕ - 75-110 μm), duration - 1 min. End footnote

Meanwhile, in this manner we obtain a depolished surface which looks very different from that of the test pieces modified by J. P. Girard, and additional polishing is necessary in order to restore a comparable surface state.

The set of observations and simulations show that it would be necessary to apply compressive force perpendicular to the surface of the plates, thus creating heterogeneous plastic flow in the cross section, in order to duplicate the essential aspects of the physical properties observed on the metal plates locally and superficially hardened by J. P. Girard. The mechanical energy required for simulating such a modification can be estimated according to the compression simulation test: we find 1.6 J.

We can also produce rings of this type by neutron irradiation.

Conclusion

The group of observations made on the duraluminum plates given to J. P. Girard makes it possible to state:

- that the required hardening was definitely realized four times during the test;

- that no simple metallurgical operation known to the authors makes it possible exactly duplicate the different physical peculiarities observed in the locally hardened zones.

Discussion and Conclusion

In this report, we described some deformations and transformations of metals obtained under specific conditions. The places in which these tests were made and the individuals who observed them were varied; the only constant presence, common to all of the tests, was that of J. P. Girard himself. Thus, there was a correlation between his presence and the appearance of the particular effects observed. Therefore, it appears that we have the right to say that J. P. Girard is part of the "cause" of these effects. But during these deformations or transformations, we neither observed nor recorded any intervention of muscular forces or physical effects on his part capable of causing them.

It thus appears that we can conclude the "abnormal" nature of these effects, especially if we consider the following observations:

- for one of the deformed test pieces (see "Session of 27 October 1976"), the nature of the measures taken to mark the piece and the process of following the deformation by successively tracing

the profiles proves that no substitution occurred; we feel that the very high strength of this test piece is enough to exclude all explanations by purely manual and muscular action;

- for the other test piece deformed in the glass tube ("Session of 31 March 1976"), the working procedure seemed to establish that the deformation, although slight, was sufficiently clear and was made while the test piece was in the tube;

- for cases of local structural transformation, by a martensitic transformation ("Tests on Stainless Steel in Closed Tubes") or by the creation of many small dislocation rings ("Local Modifications... Metallic"), the precautions described show that no substitution occurred. The generation of these effects in the tube or upon slight contact eliminates any "normal" explanation. Even if substitution did occur, we must point that we found it impossible to either reproduce all of the physical peculiarities of the test pieces transformed in this manner, or to imagine any simple metallurgical operation capable of doing it. Our simulation tests essentially permitted us to duplicate the new structural elements generated during the tests made with J. P. Girard. By combining several of these actions in a complex manner (actions which would otherwise have left traces on the specimen), we might be able to simulate the local texture and arrangement of these structural elements, but we would produce much

greater changes in dimensions than those observed, which are very slight or nonexistent. The localized nature of these transformations is surprising.

These experiments are part of a group of many more tests, which we screened and subjected to an extensive critical study under the conditions described in the introduction. This group of tests also contains those in which nothing happened, and others in which we clearly observed muscular impetus coupled with positively "abnormal" effects.

It is a good idea to emphasize that the effects observed have a certain degree of reproducibility: the bends in the bars were produced repeatedly, the local martensitic transformations - twice, and the local hardenings - four times. The last of these four tests, the test sponsored by Professor Hasted, is the most significant, for it includes the measurement of hardness before the tests in the zone in which hardening subsequently was realized, and because the increase in hardness was verified in two independent laboratories, thus an English laboratory working "blind."

J. P. Girard did not produce unknown structures in any of the tests. The structural modifications observed are of the type produced by certain types of deformations. Their distribution is normal for

the case of simple bending, but abnormal for transformations without deformation or with slight deformation.

If the effects had been produced by applying forces, the work which it would have been necessary to expend for the largest test piece would have reached around 12 J. The corresponding increase in enthalpy would be from 2-3 J.

In this article, we have no intention of imposing our conclusions as complete scientific facts. But we felt it our duty to objectively describe the conditions and the results of these experiments. We found no explanation for the effects observed, neither in current physics, nor by possible trickery, but perhaps others will be able to find them.

CONCERNING THE ARTICLE BY CH. CRUSSARD AND J. BOUVAIST

The above article was written following experiments which demonstrated the abnormal behavior of metals or alloys in the presence of J. P. Girard. I can confirm that these experiments were made with considerable scientific strictness, in order to eliminate any trickery as much as possible. However, some of them were not convincing, for the possibility of trickery is always present.

Many phenomena are rejected by the educated world because they are considered to be irrational; but this is more the a priori refusal to try to observe and control them for themselves, with concern for the truth, rather than giving proof of scientific honesty.

Several scientists did not hesitate to participate in the experiments of J. P. Girard, simply in order to "see" them objectively. I myself had this opportunity and I was sometimes troubled by these experiments, which, as one of us pointed out, places us, the physicists, in a very uncomfortable position.

Out of all of these experiments, most of which were video

recorded with a considerable abundance of controls, C. Crussard and J. Bouvaist used only those which are the subject of this article. Until proven otherwise, it was not possible to find a rational explanation for the transformations observed and described - which naturally does not mean that we will not find one later.

The authors of this article found it interesting to publish their observations, knowing full well that they would come up against rather general scepticism - but one must only view their actions as the desire to make known phenomena which are obviously inexplicable in the current state of our knowledge.

I myself agreed to add these few lines, having had occasion to follow these experiments rather closely, simply in order to give my advice about the scientific strictness with which they were conducted by the authors. Too many factors are still undetermined to make it possible to give a valid interpretation.

J. J. Trillat, Member of the Academy of Sciences

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